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INTEGRATED LABORATORY
"REAL-TIME INTERACTIVE COMMUNICATIONS SIMULATION"

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Abstract

The Avionics Laboratory, Wright Patterson Air Force Base OH, is developing capabilities to perform Research and Development (R&D)/Test and Evaluation (T&E) of advanced avionics technologies. The Integrated Electromagnetic System Simulator (IESS), Integrated Test Bed (ITB), and the Integrated Defensive Avionics Laboratory (IDAL) are key Avionics Laboratory facilities that enable development of these capabilities. IESS supports R&D/T&E of integrated Communication, Navigation, Identification (CNI) systems. ITB supports R&D/T&E of advanced avionics architectures. IDAL supports R&D/T&E of advanced Electronic Warfare (EW)/Electronic Counter Measures (ECM) technologies. This paper describes how these facilities could be interfaced to provide a realistic, interactive communications simulation that produces real, dynamic, Radio Frequency (RF) signals to evaluate approaching integrated avionics technologies including Integrated Communication, Navigation, Identification Avionics (ICNIA), PAVE PILLAR, PAVE PACE, and Integrated Electronic Warfare System (INEWS).

Need for Integrated Laboratory Testing

Avionics Laboratory facilities, such as IESS, ITB, and IDAL, have their own set of unique capabilities. These capabilities represent the state-of-the-art in research and development facilities for the specific technology areas that each is responsible for (CNI, avionics architecture, EW/ECM). With the inevitability of fully integrated avionics systems defined by the PAVE PILLAR concept, a present need exists for combined avionics R&D/T&E capabilities. Combined CNI/EW R&D/T&E capabilities will allow evaluation of the affects these subsystems have on each other within integrated avionics architectures. This will lead to identification of problem areas that can be addressed while the technology is still in the laboratory. With the added realism of interactive "operator-in-the-loop" testing, along with an interactive "combat" simulation model, the laboratory could closely simulate the affects of an actual operational flight test while continuing to have the flexibility, control, and lower cost of ground testing.

Current Capabilities

IESS generates advanced RF signals in the 2Mhz-5Ghz frequency range and emulates the aircraft avionics interfaces to provide a real-time, dynamic, integrated environment for communications testing. IESS scenarios are defined upfront by a user through a host processor subsystem (VAX 11/780). These scenarios include platform types (fixed, moving, ground, or airborne); platform positions; waypoints; and RF signals to be utilized. Single board computers called device controllers control waveform generators which produce complex RF signals to simulate the environment that exists between platforms during an actual flight test. The waveform generators consist of off-the-shelf test equipment, a Global Positioning System Simulator (GPSS), and an embedded ICNIA Advanced Development Model (ADM) terminal called the Integrated Signal Support Unit (ISSU). A list of the complex signals that are produced by these generators is provided in Table 1.

An interim capability is currently provided which produces the signals identified with an asterisk (*). The HF, VHF and UHF signals are only tones for the interim system. Full capability to include all of these signals will be provided upon integration of the ISSU (embedded ICNIA). IESS is located in a secure TEMPEST facility on the 3rd floor of Building 620, Wright-Patterson AFB.

- ARC-199 High Frequency (HF) Radio Waveform*
- ARC-186 Very High Frequency (VHF) Radio Waveform*
- Single Channel Ground/Airborne Radio System (SINCGARS-V) VHF Electronic Counter-Counter Measures (ECCM) Waveform
- ARC-164 Ultra-High Frequency (UHF) Radio Waveform*
- HAVE QUICK II Radio Waveform
- Enhanced Position Location Retrieval System (PLRS) User Unit (EPPU) Waveform
- Global Positioning System (GPS) Waveform*
- Class 2 Joint Tactical Information Distribution System (JTIDS) Waveform
- Instrument Landing System (ILS) Marker Beacon, Localizer, and Glideslope Waveforms*
- VHF Omnidirectional Range (VOR) Waveform*
- ARN-118 Tactical Airborne Navigation (TACAN) Waveform*
- MARK XII Interrogate Waveform
- MARK XII Transponder Waveform
- Mode S Waveform
- Traffic Collision and Avoidance System (TCAS-I) Waveform
- Microwave Landing System (MLS) Waveform*

Table 1. IESS Functional Capabilities

The ITB provides real-time simulation of military aircraft in an operational environment which includes aircraft dynamics, aircraft sensors, weapons, and targets. ITB equipment generates interface signals between the aircraft sensor suite and the avionics system that subject avionics equipment under test to data signal environments that are nearly identical to actual flight. A simulated cockpit is provided equipped with six color CRTs, Heads up Display (HUD), pedals, stick control, throttle, and switches to interface a pilot/engineer to the ITB for interactive "operator-in-the-loop" simulations. An out-the-window system provides symbolic background scenes outside the cockpit so that the pilot operator experiences visual orientation of flight with respect to intercept points, targets, and runways. Simulation software resident on a Harris 800 complex is driven by a scenario generator or interactively from the cockpit by an operator acting as a pilot. A list of the major components that make up the ITB facility is provided in Table 2.

- Avionics Equipment
  -- Flight Processors
  -- Multiplex Buses
  -- High Speed Data Buses
  -- Equipment Under Test
  -- Operational Flight Programs
- Real-Time Simulation Computers
- Simulation Software
- Out-The-Window Scene
- Crewstation
- Display Generation System
- High Speed Simulation Network
- ITB Support Hardware and Software
- System Test Software

Table 2. ITB Major Components

The ITB is located on the 3rd floor of Building 620 and is performing demonstrations and evaluations of advanced avionics architecture technologies such as the Very High Speed Integrated Circuits (VHSIC) Avionics Module Processor (VAMP).

The IDAL provides a real-time, dynamic, integrated RF environment analogous to IESS for R&D/T&E of EW/ECM systems. As part of the IDAL concept, a real-time interactive combat simulation model entitled SUPPRESSOR which presents "pop up" threats to a user operating a host platform is hosted in Combat Electromagnetic Environment Simulator (CEESIM) hardware. SUPPRESSOR allows users to define, at many detailed levels, the characteristics, interactions, and interrelationships of participants in a multi-sided conflict of combined air, ground, naval, and space forces. SUPPRESSOR has already been interfaced with the ITB such that a user operating the ITB cockpit can interact with SUPPRESSOR threats.

The IDAL concept is still in design; however, equipment is available from the CEESIM and other hardware located on the 1st floor of Building 620 to perform preliminary interfacing of these facilities.

Objective/Goals of the Integrated Laboratory

The specific objective of the Integrated Laboratory is to design and implement an interface between the IESS, ITB, and IDAL facilities. The interface will include interactive combat simulation using the SUPPRESSOR model hosted in the IDAL facility. SUPPRESSOR is expected to be the high level simulation that drives the interface. It is desired that the interface design allow for future growth to include offensive avionics facilities and software support facilities such as the Advanced Multi-Purpose Support Environment (AMPSE).

Three main goals have been identified in support of the overall objective of an Integrated Laboratory: 1) Perform real-time interactive simulations utilizing the ITB (cockpit) and IESS; 2) Perform real-time interactive "combat" simulations utilizing the ITB, IESS, and SUPPRESSOR hosted in IDAL; and 3) Perform integrated CNI/EW RF testing of ICNIA in IESS using real-time interactive combat simulations from the Integrated Laboratory interface.

Integrated Laboratory Interface Approach

A series of demonstrations will be accomplished in support of the goals of the interface. These demonstrations will build upon one another permitting the interface to evolve naturally into an Integrated Laboratory. Figure 1 illustrates this approach. Demonstrations are listed in support of real-time interactive simulations, real-time interactive combat simulations, and finally integrated CNI/EW RF testing of ICNIA with the completed interface. These demonstrations will show IESS integration with the ITB then with the SUPPRESSOR combat simulation model and finally integrated testing of ICNIA with the full integrated laboratory interface. Other more detailed demonstrations and experiments are expected as the interface evolves. This low risk approach will help identify new capabilities for R&D/T&E of integrated avionics technologies while at the same time demonstrate the feasibility of the integrated laboratory concept.

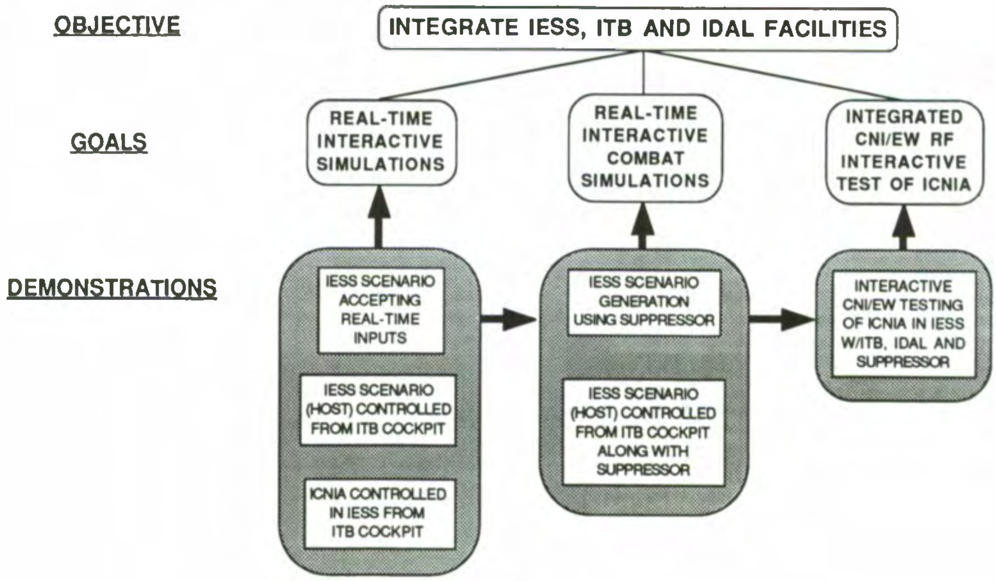

FIGURE 1. INTEGRATED LABORATORY APPROACH

Figure 2 shows the Integrated Laboratory interface. Each facility has its own unique set of processors, data buses, software, etc. that must be interfaced. ITB uses a Harris 800 complex to host its simulation software. IESS uses a VAX 11/780 to host its simulation software along with single board computers that control the waveform generators (GPSS, ISSU, and off-the-shelf test equipment). IDAL uses a MicroVAX II to host the SUPPRESSOR software and a MicroVAX III to control CEESIM digital and RF generation equipment. MicroVAX II computers are also used for control of the interfaces between ITB and IDAL.

Five main interfaces have been identified to date: ETHERNET, MIL-STD-1553B, RS232, RS170, and an RF link between IESS and IDAL. ETHERNET is a low risk approach that will provide overall control of a fiber optic link that exists between the facilities. ETHERNET will support process control, file transfer, data transfer, and terminal access through the fiber optic link. Consideration may also be given to the Shared Memory Asynchronous Real Time Network (SMARTNET) to replace the ETHERNET in the future. SMARTNET, with its larger bandwidth network protocol, may be necessary as data rate requirements increase. The MIL-STD-1553B high speed avionics data bus will be used between the IESS and ITB to control the ICNIA Unit Under Test (UUT). MIL-STD-1553B messages will be sent from the ITB cockpit to the ICNIA UUT in IESS to modify which ICNIA functions are in use. Feedback from ICNIA over the MIL-STD-1553B will include position, velocity, and acceleration that can be displayed to the user operating as a pilot in the ITB cockpit. An RS232 will also be available to provide the capability to remotely control processors in one laboratory with terminals in the other laboratories. An RS170 link will provide an audio/video data link between laboratories. Finally, an RF link between IESS and IDAL will be available to support integrated CNI/EW RF testing of the ICNIA UUT.

Real-Time Interactive Simulations using IESS

To accomplish an Integrated Laboratory interface between IESS, ITB and IDAL, real-time interactive simulations must be possible within IESS. Currently, IESS is designed to test and evaluate advanced CNI systems in a real-time, dynamic, RF environment. This environment is highly repeatable in that defined scenarios can be saved and used over and over. However, it is not interactive, i.e., once scenario execution is started, the scenario cannot be changed. Figure 3a illustrates the present approach. Three separate processes are required to produce the signals to perform a real-time dynamic test:

1) Scenario Definition (non-real-time)
2) Scenario Generation (non-real-time)
3) Scenario Execution (real-time)

Scenario generation utilizes an ORACLE database in conjunction with IESS Environment Simulation (ESIM) software to generate a run package that includes all the commands and messages to perform scenario execution in real-time. The time required to generate an executable batch file varies considerably with the complexity of the defined scenario. According to specification, the maximum ratio of time required to generate the batch file versus the actual time required to execute the scenario is 4:1.

Figure 3b illustrates a possible approach to providing a real-time interactive capability to IESS. This approach would eliminate ORACLE from the process in favor of a new software "controller" (ESIM Front End) that would reformat initial scenario definition inputs and combine them with the inputs of an interactive operator in the loop for

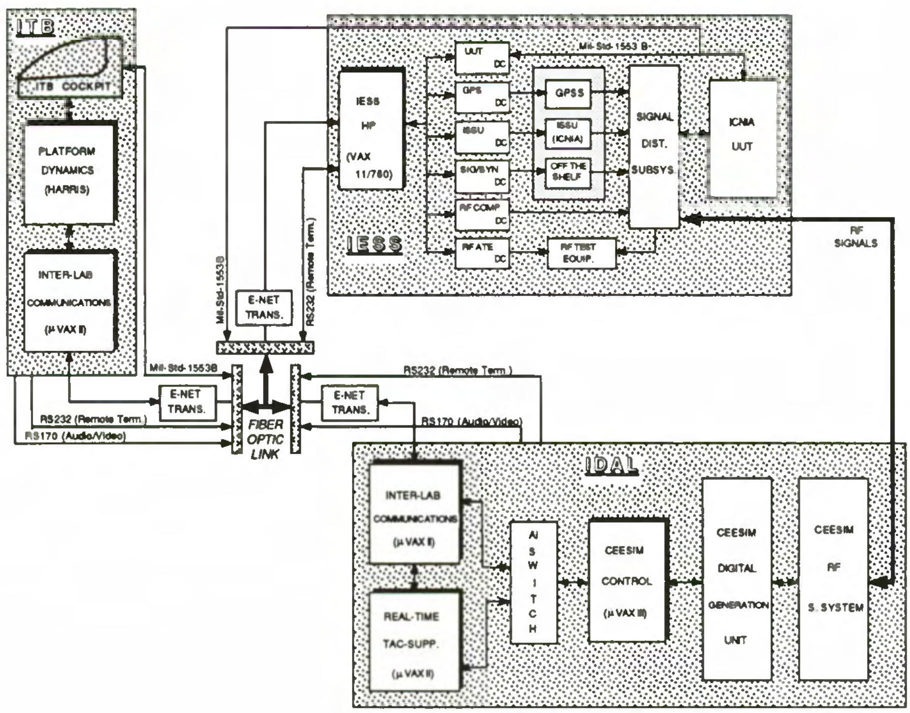

FIGURE 2. INTEGRATED LABORATORY INTERFACES

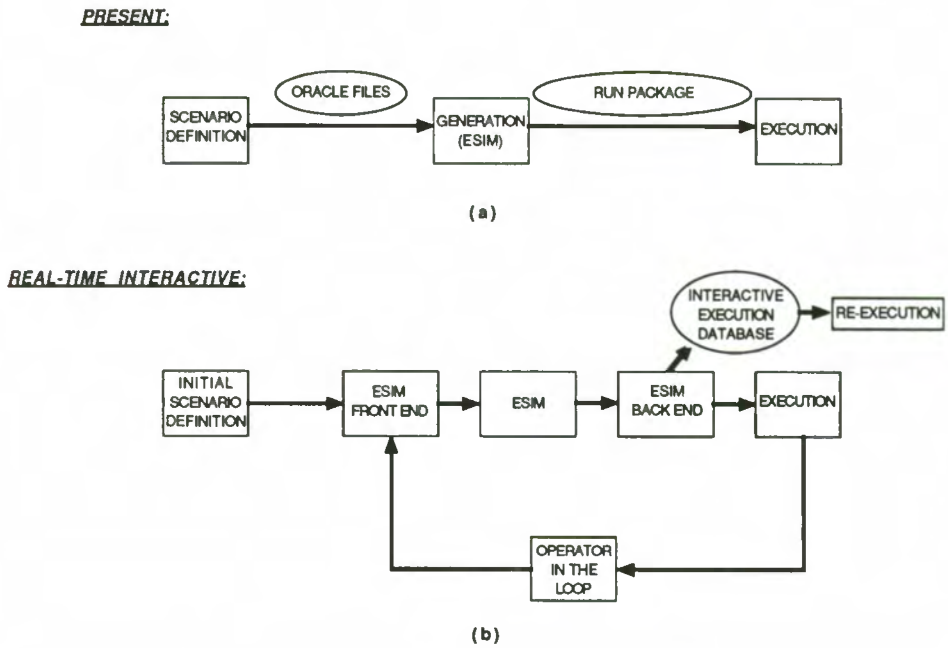

FIGURE 3. IESS REAL-TIME INTERACTIVE CAPABILITY

input into ESIM software. ESIM Back End software would would be developed to take the results from ESIM and reformat them for immediate scenario execution. Therefore, simultaneous scenario generation and execution could be done that would enable IESS to operate in a "pseudo" real-time interactive mode (i.e. some delays are inevitable). To preserve IESS's repeatability, the scenario execution commands could be stored in a data base while the interactive scenario is occurring for re-execution at a later time. It is hoped that the elimination of ORACLE along with performance enhancement of ESIM software will speedup the simulation such that any delays are small enough not to be noticed by the user.

Figure 4 shows a graph illustrating what is termed "simulation time elasticity." The graph shows certain events being processed behind schedule, while following events are processed at the correct time. Effectively, a simulation attempts to catch up to real time when the event processing falls behind schedule. This is a characteristic of the real-time implementation of SUPPRESSOR. Ideally, simulation time always equals real time. Such is the case for the initial and final events of the example in Figure 4. Event clusters, however, cause transitory simulation time variances (lags) from real time. Reacquisition of real time is possible only if there is sufficient time between the processing of events to compensate for the

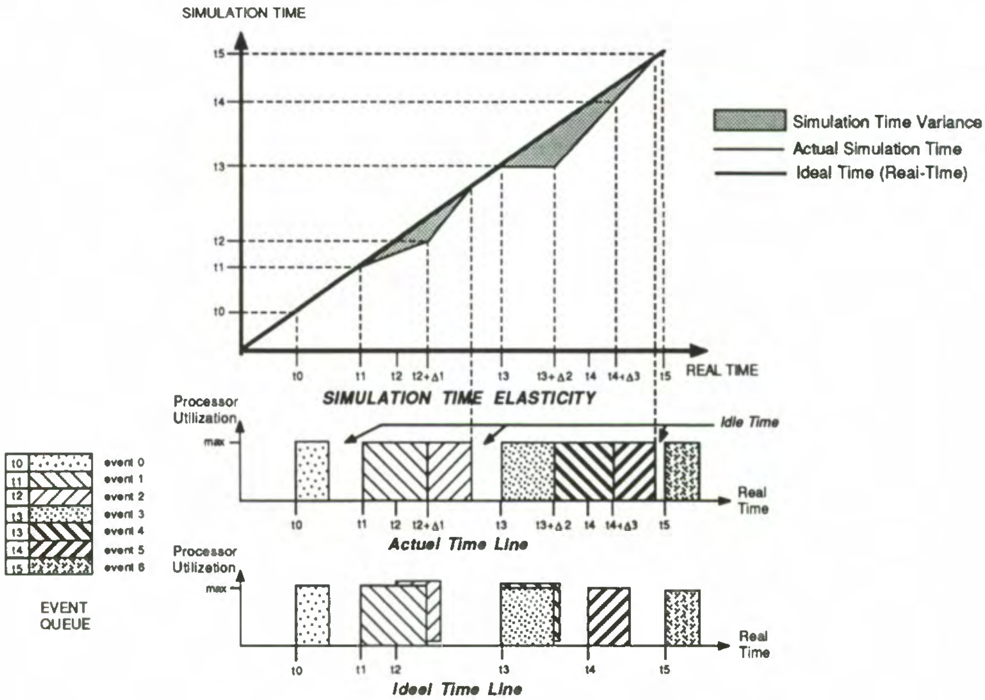

FIGURE 4. SIMULATION TIME ELASTICITY

simulation time delay. If the ideal time line of a scenario contains more event overlap than idle time, simulation time will lag behind real time and the amount of lag will increase as the simulation progresses.

The significance of this to the Integrated Laboratory interface is that, to demonstrate the first goal, i.e., IESS/ITB Real-Time Interactive Simulation, IESS must also be capable of processing real time interactive inputs in time for the overall scenario to "catch up" so that time lags are unnoticed by the user. Therefore, the current ratio of scenario generation time versus scenario execution time (currently 4:1 maximum) must be greatly improved in order for real time inputs to become feasible. [Note from Figure 4 that the ratio must be significantly greater than real-time (1:1) for the scenario to ever catch up.] Once IESS is modified to accept real-time interactive inputs, demonstrations involving an operator-in-the-loop utilizing the ITB cockpit and the SUPPRESSOR model hosted in IDAL can proceed.

Benefits of an Integrated Laboratory Interface

Undoubtedly the benefits of an interface that provides integrated testing among avionics subsystems are many, including: lower risk technologies that are more fully tested in the laboratory, development of new diagnostics technologies and techniques, development of new integrated test facility techniques, combined CNI/EW R&D leading to new or enhanced technologies and techniques, and R&D into adaptive communications as well as identification of EW techniques susceptible to communications signals. This interface may also enable enhanced testing of software which represents a tremendous challenge to the logistics community regarding integrated avionics architectures such as ICNIA, INEWS, and PAVE PILLAR. IESS scenario definition is also expected to be greatly enhanced with an operator in the loop since complicated host platform movements will not need to be defined and laid out in detail ahead of time. This would be a significant time saver for users of the IESS.

Management Issues and Concerns

The IESS, ITB and IDAL, at present, are all "interim" facilities with interim capabilities. As such, development is still ongoing in each to bring the facilities to a point where significant R&D/T&E can be performed. In light of this, access to these facilities to perform experiments in support of the Integrated Laboratory interface may be difficult. In particular, IESS is gearing up to perform T&E on ICNIA Advanced Development Model (ADM) terminals being delivered to the Air Force in 1990. Much time will be required within IESS to integrate the ISSU and ICNIA making less time available to perform experiments in support of the Integrated Laboratory interface. Cooperation between support and developing contractors working in the facilities may also cause unique problems in providing timely and accurate technical information. These issues are being examined by management within the Avionics Laboratory and will be resolved before proceeding with the interface.

Conclusion

The Avionics Laboratory is pursuing the development of interfaces that enable integrated testing between subsystems (CNI, EW, avionics architectures, etc.). IESS, ITB, and IDAL are expected to play key roles in bringing advanced avionics technologies into the Air Force inventory. This paper proposes development of interfaces between these facilities to produce new capabilities and techniques that lower the risk associated with approaching integrated avionics technologies such as ICNIA, PAVE PILLAR, and INEWS as well as future technologies such as those that will come from PAVE PACE. The specific objective of this effort will be the realization of a real-time interactive communications simulation capability that enables realistic integrated CNI/EW RF testing of advanced avionics technologies.

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